

# **Appendix M**

## **Development of Extraction Scenarios**

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## DEVELOPMENT OF EXTRACTION SCENARIOS

### 1.0 INTRODUCTION

This Section describes nine extraction scenarios that were simulated using the project flow model. The extraction scenarios were simulated for the purpose of comparing the efficiency and feasibility of remediation extraction systems for the Newmark plume.

In evaluating extraction scenarios, it was assumed that TCE and PCE travel at the same velocity as the groundwater. This simplification was necessary because the modeling software is only capable of calculating groundwater velocities, not contaminant velocities. This assumption is reasonable because, as shown in Section 13.2, the retarded velocities for TCE and PCE are not substantially different from the groundwater velocities. The project flow model described in Section 3.0 served as the basis for the extraction scenario simulations.

### 2.0 EXTRACTION SCENARIOS AND EXTRACTION REGIONS

A total of nine extraction scenarios were simulated. The extraction scenarios were consisted of extraction areas located in one or any combination of four extraction regions of the Newmark plume, with the exception of extraction scenario no. 9. The extraction area locations determined in each of the extraction scenarios are for analysis only. The exact locations of extraction areas will be identified during the design phase. Extraction scenario no. 9 was simulated without using any additional extraction areas, other than the existing water-supply wells. The extraction regions of the Newmark plume were:

- Downgradient edge of the Newmark plume;
- Middle of the Newmark plume (adjacent to the eastern edge of Shandin Hills);
- Newmark Wellfield; and

- Centerline of the southern half of the Newmark plume.

The downgradient edge of the Newmark plume was chosen as a extraction region for the main purpose of preventing further downgradient migration of the Newmark plume. The middle of the Newmark plume was chosen as a extraction region because it was a strategic location for narrowing the width of the Newmark plume and dividing it into two plumes that could be remediated independently. The Newmark wellfield was chosen as a extraction region because it was a suspected source area for the Newmark plume that could be remediated separately from the remainder of the Newmark plume. The centerline of the Newmark plume was chosen as a extraction region for the purpose of remediating the southern half of the Newmark plume in one efficient system of extraction wells. Figure 1 shows the study area with the estimated location of the plume and the extraction scenario areas.

The nine extraction scenarios were:

- Extraction scenario no. 1 was simulated for a duration of 5 years using extraction areas located at the downgradient edge of the Newmark plume;
- Extraction scenario no. 2 was simulated for a duration of 5 years using extraction areas located in the Newmark Wellfield;
- Extraction scenario no. 3 was simulated for a duration of 5 years using extraction areas located in the middle of the Newmark plume;
- Extraction scenario no. 4 was simulated for a duration of 5 years using extraction areas located along the centerline of the Newmark plume;
- Extraction scenario no. 5 was simulated for a duration of 35 years using extraction areas located at the downgradient edge of the Newmark plume;

- 1       ■ Extraction scenario no. 6 was simulated for a duration of 35 years using extraction areas located  
2       at the downgradient edge of the Newmark plume and in the Newmark wellfield;
- 3       ■ Extraction scenario no. 7 was simulated for a duration of 35 years using extraction areas located  
4       at the downgradient edge of the Newmark plume, in the Newmark wellfield, and in the middle  
5       of the Newmark plume;
- 6       ■ Extraction scenario no. 8 was simulated for a duration of 35 years using extraction areas located  
7       along the centerline of the southern half of the Newmark plume and in the Newmark wellfield  
8       of the Newmark plume; and
- 9       ■ Extraction scenario no. 9 was simulated for a duration of 35 years using only the existing water-  
10      supply wells.

11      Extraction scenarios no. 1 through 4 were simulated for a short-time span of 5 years and were simulated  
12      for each of the four extraction regions. The first four extraction scenarios were preliminary scenarios  
13      simulated for the purpose of quickly estimating the number of extraction wells (with their locations and  
14      pumping rates) that would be required to capture the Newmark plume at each of the four extraction  
15      regions.

16      Extraction scenarios no. 5 through 8 were simulated for 35 years using combinations of the extraction area  
17      locations for the four extraction regions. Extraction scenarios no. 5 through 8 were final scenarios  
18      simulated for the purpose of comparing the efficiency and feasibility of extraction systems for remediating  
19      the Newmark plume.

20      Extraction scenario no. 9 was simulated for 35 years using just the existing water-supply wells. This  
21      extraction scenario was also known as the "no action" scenario. Extraction scenario no. 9 was used to:

- 22      ■ Estimate the position of the Newmark plume 35 years from January 1986;

- 1       ▪ Evaluate whether any existing water-supply wells within the Newmark plume had an influence
- 2       and could be utilized as possible extraction areas for the Newmark plume; and
- 3       ▪ Calculate groundwater velocities for three areas of the Newmark plume.

4 Information from extraction scenario no. 9 was also used for estimating the time required to remediate the  
5 Newmark plume. The remediation times were estimated based on the groundwater velocities calculated  
6 for the three areas of the Newmark plume. The calculations of the remediation times are described in  
7 Section 14.0.

8 Several simulations were made before the final simulation for each extraction scenario was achieved. Table  
9 35 at the end of this Appendix contains a list of input and output files for the simulations made relative to  
10 the extraction scenarios. A description of objectives, data, procedures and results for each extraction  
11 scenario will follow in Sections 4.0 through 12.0.

### 12   3.0 REVIEW OF PROJECT FLOW MODEL

13 The project flow model serves as the basis for the extraction scenario simulations. Development of the  
14 project flow model consisted of several processes:

- 15       ▪ Development of the conceptual model.
- 16       ▪ Definition of the model area.
- 17       ▪ Preparation of the input data.
- 18       ▪ Definition of the grid system.
- 19       ▪ Calibration of the steady-state and transient-state flow models.

1 Development of the conceptual model and definition of the model area are described in Section 1.4 of  
2 Appendix J. Preparation of the input data and boundary conditions for the transient-state model (which  
3 eventually becomes the project flow model) is described in Section 2.4 of Appendix J. The final input data  
4 used in the project flow model is described later in this section. Details on the calibration of the steady-  
5 state and transient-state flow models can be found in Sections 2.2 and 2.5 of Appendix J. A brief  
6 description on the calibration of the steady-state and transient-state models as they pertain to the project  
7 flow model and the extraction scenario simulations is given below.

8 The steady-state flow model was simulated and calibrated for the time period between January 1982 to  
9 January 1986. The input data and boundary conditions are described in Section 1.5 and 2.3 of Appendix  
10 J. The transient flow model was simulated and calibrated for the time period between January 1986 to  
11 December 1990. The input data and boundary conditions, resulting from the calibration of the steady-state  
12 flow model, were used as the initial conditions for the transient-state flow model. Some of the input data  
13 and boundary conditions (ie. transmissivities, recharge values) were refined in order to calibrate the  
14 transient-state flow model. The calibrated transient-state flow model then became the project flow model  
15 which was used for simulation of the extraction scenarios. The measured recharge, streamflow, pumpage,  
16 and head values for this time period were used in the extraction scenario simulations.

17 MODFLOW (McDonald and Harbaugh, 1988) was the groundwater flow program used to simulate the  
18 groundwater flow for the Newmark model area. PATH3D (Zheng 1991) and SURFER (Golden Software,  
19 Inc. 1990) were used as post-processors for the MODFLOW output data. PATH3D, a groundwater path  
20 and travel-time program, utilized the input data and unformatted head files of MODFLOW simulations to:

- 21       ■ Create contours of the calculated heads;
- 22       ■ Simulate the pathlines of imaginary particles placed in various areas of the Newmark plume; and
- 23       ■ Delineate capture-zones for each extraction scenario.

SURFER (Golden Software, Inc. 1990) is a graphics program, which utilizes the head contour files created by PATH3D to produce plots displaying the head contours, particle pathlines and locations of the extraction areas.

### **3.1 Grid System**

A grid system with constant grid spacing was constructed for the preliminary steady-state model. The grid system consists of 3360 square cells (42 columns and 80 rows). Each cell measures 820.25 feet in both the x- and y-directions. The grid system for the study and model area is displayed in Figure 2 of Appendix K.

### **3.2 Input Data for Project Flow Model**

The input data for simulation of the project flow model was arranged into seven categories of input files:

- Hydrogeologic layers.
- Boundary layers.
- Initial head conditions.
- Percolation basins and ponds.
- Hydraulic conductivity and transmissivity values.
- Well pumpage.
- Vertical leakance values.

### 3.3 Hydrogeologic Layers

The model area consists of igneous and metamorphic basement rock that was downdropped between the San Andreas and San Jacinto faults. The basin is filled with alluvial deposits which spread around the bedrock hills and reach a thickness of at least 2100 feet in the southern portion of the model area northeast of the San Jacinto fault (Hardt and Hutchinson 1980). From here, the basin deposits become progressively thinner towards the northwest and north near the San Bernardino Mountains. Figure 15 in Appendix J shows interpreted thickness of the alluvium for the model area. Figure 15 in Appendix J was modified from Hardt and Hutchinson (1980) using additional well information. Figure 16 in Appendix J depicts the interpreted surface of the bedrock for the model area.

Several cross-sections were constructed from a detailed analysis of approximately 100 drillers' logs. Interfingering clay lenses that are evident in the individual drillers' logs were grouped together into one middle clay unit that acts as a confining layer for the lower aquifer. Table 1 in Appendix J shows the top and bottom elevations of the middle confining clay unit chosen from each drillers' log. The detailed cross-sections were then compiled into two conceptual cross-sections. Figure 5 in Appendix J shows the locations of the conceptual cross-sections. Figure 6a in Appendix J represents a north/south cross-section and Figure 6b in Appendix J represents an east/west cross-section.

After further analysis of the cross-sections, the model area was divided into two major aquifers. The area north of Shandin Hills consists of one unconfined aquifer. The area just south of Shandin Hills is comprised of two aquifers: the upper aquifer, an extension of the unconfined aquifer north of Shandin Hills and the lower aquifer, a separate, confined aquifer. However, for modeling purposes the aquifer north of Shandin Hills was separated into two aquifers by extending the middle confining clay unit through this area at a "zero-foot" thickness and making the lower aquifer (layer 2) approximately 25 feet thick.

To further define the aquifer system for model representation, two structure maps were constructed for the middle confining clay unit using the elevations listed in Table 1 of Appendix J. Figure 7 in Appendix J shows the elevations for the top surface of the middle confining clay unit, and Figure 17 of Appendix J shows the elevations for the bottom surface of the middle confining clay unit.

1 The middle confining clay unit is predominantly clay but includes varying amounts of sand and gravel.  
2 The unit is at least 300 feet thick in the central part of the study area near the 7th Street well and thins  
3 towards the northern parts of the study area. The top surface of the middle confining clay unit ranges from  
4 1016 feet above sea level at the Darby well just south of the southwest corner of Shandin Hills to  
5 approximately 580 feet above sea level in the central part of the model area near Warm Creek.

6 The middle confining clay unit was not modeled as a separate hydrologic layer but rather its thickness was  
7 embedded in the vertical leakance values for the overlying unconfined aquifer (layer 1). The vertical  
8 leakance values for the middle confining clay unit will be discussed in more detail later in this section.  
9 The upper model layer (layer 1) is above the middle confining clay unit and the lower model layer (layer  
10 2) is below the middle confining clay unit. The greatest thickness of water-bearing deposits is in layer 2.  
11 The bottom elevations for layer 1 will correspond to the top elevations of the middle confining clay unit  
12 and the top elevations for layer 2 will correspond to the bottom elevations of the middle confining clay  
13 unit. Since the designated bottom of layer 1 and top of layer 2 do not coincide in the southern area of the  
14 model area, the project flow model recognizes the break between the layers as a middle confining clay unit.  
15 The actual thickness of the middle confining clay unit is figured into the vertical leakance values, which  
16 will be described later in this section.

### 17 **3.4 Boundary Conditions**

18 The boundary conditions for the model area were defined by the geometry of the model area, by the  
19 groundwater/surface water flow conditions, and by the geologic structures (faults, subsurface groundwater  
20 barriers, and impermeable bedrock features) in the area. Several boundary condition subroutines that are  
21 available in the project flow model were used to represent the actual boundary conditions within the model  
22 area. Actual boundary conditions for the model area were represented in the project flow model as no-  
23 flow and head-dependent conditions. The boundary conditions are assigned to the individual cells of the  
24 model, both for layers 1 and 2.

### 3.4.1 No-flow Conditions

No-flow conditions were simulated in the model for several impermeable areas that include bedrock hills, mountains, and fault zones. Shandin Hills, Badger Hill, Wiggins Hill, and Perris Hill are bedrock hills that impede groundwater flow within the model area. The San Andreas and San Jacinto faults form no-flow boundaries that border the northeastern and southwestern boundaries of the model area. Figure 18 in Appendix J displays the no-flow cells (impermeable areas). The hydraulic conductivity values for the upper versus lower aquifers of the southern region of the model area will be discussed later in this section.

### 3.4.2 Head-dependent Conditions

Head-dependent conditions were simulated using the General-head Boundary package. Head-dependent conditions were assigned to the eastern and western boundaries of the model area. Head-dependent conditions were also assigned to the most upgradient and downgradient positions of the streams where they enter or leave the model area. Furthermore, head-dependent conditions were assigned to the upper aquifer cells since the streams influence only the upper aquifer.

Head-dependent conditions were assigned to the most upgradient or downgradient positions of the following streams and canyons which are displayed in Figure 18 of Appendix J:

- The upper cell of Devil Canyon where it intersects the San Andreas fault.
- The upper two cells of Waterman Canyon where it intersects the San Andreas fault.
- The upper eleven cells of Lytle Creek Wash located on the western boundary of the model area.
- The upper cell of East Twin Creek located on the eastern boundary of the model area.
- The upper five cells of the Santa Ana River located on the eastern boundary of the model area.

- 1       ■ The upper cell of San Timoteo Wash located on the eastern boundary of the model area.

- 2       ■ The lower six cells of the Santa Ana River where it crosses the San Jacinto fault.

3 Head-dependent conditions allow for flow to enter or leave a cell  $i,j,k$  from an external source. The  
4 location of each cell  $i,j,k$  is designated by the row (i), column (j), and layer (k). This flow,  $Q_{bi,j,k}$ , is  
5 proportional to the difference between the head in the cell,  $h_{i,j,k}$ , and the head assigned to the external  
6 source,  $h_{bi,j,k}$ . Thus, a linear relationship between flow into the cell and head in the cell is established,

$$7 \qquad Q_{bi,j,k} = C_{bi,j,k} (h_{i,j,k} - h_{bi,j,k}) \qquad (1)$$

8 where,  $C_{bi,j,k}$  is the conductance between the external source and cell  $i,j,k$  (McDonald and Harbaugh, 1988).  
9 Conductance equals the horizontal hydraulic conductivity times the cross-sectional area of the external  
10 source.

11 Several input parameters were needed to simulate the flow across the head-dependent cells:

- 12       ■ Heads for the external source.
- 13       ■ Cross-sectional area for the external source.
- 14       ■ Horizontal hydraulic conductivity of the external source area.

15 Flow values across each head-dependent cell for the upper and lower cells of these streams were calibrated  
16 with the streamflow data for the corresponding gaging station locations. (Table 2 in Appendix J lists the  
17 streamflow data that were used in the steady-state calibration.) Table 9 in Appendix J lists the streamflow  
18 data that were used in the transient-state calibration. Figure 10 in Appendix J illustrates the locations of  
19 the gaging stations.

### 3.5 Initial Head Conditions

The project flow model was calibrated for two phases: steady-state and transient-state. Steady-state versus transient-state is described in more detail in Section 2.1 of Appendix J. The steady-state model was calibrated from 1982 to 1986. This period was chosen to run the steady-state phase of the model because groundwater elevations remained fairly constant during this time. Also, the total inflow and outflow of water from the study area did not vary significantly during this time period (Hardt and Freckleton 1987; Duell and Schroeder 1989).

January 1982 water elevations were used for the initial head conditions. These water elevations were obtained from Hardt and Freckleton (1987). Figure 11 of Appendix J displays the January 1982 initial water elevations for the upper aquifer. Figure 12 of Appendix J displays the January 1982 initial water elevations for the lower aquifer.

The transient-state model was calibrated from January 1986 through December 1990. The January 1986 water elevations calibrated for the steady-state model were used for the initial head conditions of the transient-state model. Figure 19 in Appendix J displays the January 1986 initial water elevations for the upper aquifer. Figure 20 of Appendix J displays the January 1986 initial water elevations for the lower aquifer.

### 3.6 Surface Water and Groundwater Interaction

Surface water enters the model area through various streams flowing from the north out of the San Bernardino Mountains and from the east and west sides of the model area. Most of the surface water enters the model area through Devil Canyon and Waterman Canyon-East Twin Creek. These canyons collect runoff water from the San Bernardino Mountains. The remainder of the surface water enters the east side of the model area through Warm Creek, Santa Ana River and San Timoteo Wash, and the west side of the model area through Lytle Creek Wash. Some surface water leaves the model area intermittently through the Santa Ana River where it crosses the San Jacinto fault to the south (Hardt and Hutchinson, 1980).

1 Groundwater movement in the model area follows the surface-drainage pattern. Groundwater generally  
2 moves southward in the model area, except in the Lytle Creek area where it moves southeastward and  
3 converges toward a common line of discharge at the San Jacinto fault beneath the Santa Ana River. The  
4 potentiometric head is above the confining beds in this area, and because the San Jacinto fault restricts  
5 groundwater flow, groundwater is forced through and around the clay beds into the overlying strata and  
6 onto the land surface. Consequently, significant components of vertical flow are created in the  
7 groundwater flow regimen. Historically, potentiometric heads above land surface existed in the Warm  
8 Creek area adjacent to the north side of the San Jacinto fault (Hardt and Hutchinson 1980).

9 Surface water is piped into the model area and released at three recharge facilities (percolation basins) at  
10 the base of the San Bernardino Mountains predominantly during the dry, summer months (Figure 10 in  
11 Appendix J). Sweetwater spillway lies just south of Devil Canyon. The Badger recharge area is located  
12 to the west of Badger Hill. The Waterman Canyon-East Twin Creek facility contains percolation basins  
13 just south of Waterman Canyon.

14 Surface-water inflow and outflow for the model area has been measured at selected gaging stations (Figure  
15 10 in Appendix J). The data show, except during high flows caused by infrequent flooding, the inflows  
16 are much larger than the outflows. Thus, it is concluded that most of the surface flow that enters the valley  
17 percolates into the aquifer (Hardt and Hutchinson 1980).

18 Generally, the flow from small streams (Devil Canyon, Waterman Canyon-East Twin Creek, San Timoteo  
19 Wash, and Warm Creek) is recharged locally into the aquifer within a few miles of the mountain front.  
20 Therefore, the recharge areas for Devil Canyon and Waterman Canyon-East Twin Creek only occur at the  
21 percolation basins. South of these basins the streams function as subsurface discharge areas for  
22 groundwater in the model area. In the subsurface discharge areas of the streams, groundwater flows  
23 towards the permeable, subsurface streambeds. The groundwater is discharged atmospherically  
24 evapotranspiration where groundwater is within 10 feet of the ground surface. The recharge areas  
25 Warm Creek and San Timoteo Wash are located outside the Newmark model area to the north.  
26 Consequently, the portions of the Warm Creek and San Timoteo Wash located within the  
27 function as discharge areas for groundwater flow.

1 Large flow rates are transmitted by the larger streams (Santa Ana River and Lytle Creek) in a short time  
2 during flood periods. Surface water and groundwater discharge of these flood flows out of the model area  
3 occurs primarily where the Santa Ana River crosses the San Jacinto fault. The General-head Boundary  
4 package of the project flow model was used to simulate the groundwater flow into and out of the model  
5 area across the upgradient cells of the streams. The River package of the project flow model was used to  
6 simulate the effects of flow between the surface-water features and the groundwater system. The river  
7 package was set up so that surface water recharged the groundwater at all isolated percolation basins and  
8 percolation basins connected with the upgradient positions of the streams (Devil Canyon and Waterman  
9 Canyon-East Twin Creek). The remainder of the streams were set up as groundwater discharge areas.  
10 Figure 18 in Appendix J illustrates the model area portions effected by the streams, percolation basins, and  
11 ponds.

12 Flow between the stream and the groundwater system is characterized by

$$13 \quad \quad \quad \text{QRIV} = \text{CRIV} (\text{HRIV} - h_{i,j,k}) \quad (2)$$

14 where, QRIV is the flow between the stream and the aquifer and taken as positive if it is directed into the  
15 aquifer; HRIV is the head in the stream; CRIV is the hydraulic conductance of the stream-aquifer  
16 interconnection; and  $h_{i,j,k}$  is the head at the node in the cell underlying the stream reach. The term for the  
17 idealized streambed conductance (CRIV) as it crosses an individual cell is further defined by

$$18 \quad \quad \quad \text{CRIV} = (K L W)/M \quad (3)$$

19 where, L is the length of the stream as it crosses the node; W is the stream width; M is the thickness of  
20 the streambed layer; and K is the hydraulic conductivity of the streambed material (McDonald and  
21 Harbaugh 1988).

### 3.7 Hydraulic Conductivity Values

Hydraulic conductivity is the quantity of water that will flow through a unit cross-sectional area of a permeable material per unit of time under a unit of hydraulic gradient at a specified temperature. In the project flow model, hydraulic conductivity values were assigned for both the upper and lower aquifers. Aquifer tests (specific-capacity and pump tests) were used to quantify the hydraulic conductivity values for the model area. Table 10 in Appendix J lists the hydraulic conductivity values used in the project flow model. Figure 21 in Appendix J displays the calibrated hydraulic conductivity values used in the project flow model for layers 1 and 2.

Faults and impermeable bedrock hills were represented as either no-flow areas or with low hydraulic conductivity values. A hydraulic conductivity of  $2.83 \times 10^{-8}$  ft/day (for upper model layer) and a transmissivity of  $2.83 \times 10^{-12}$  ft<sup>2</sup>/day (for lower model layer) were used for the San Andreas and San Jacinto faults and the bedrock hills. The hydraulic conductivity values of the alluvium were used in the areas where streams cross the San Andreas and San Jacinto faults for the upper modeling layer.

### 3.8 Well Pumpage

Well pumpage (ft<sup>3</sup>/day) was also simulated in the flow model. Most of the discharge from the groundwater system in the model area is from water-supply wells. Well pumpage information for steady-state model (time period between January 1982 through January 1986) was obtained from the Western Watermaster via Wesley Danskin of the U.S. Geological Survey. Well pumpage information for the transient-state model (time period between January 1986 through December 1990) was obtained from various water agencies:

- City of San Bernardino Water Department
- City of Riverside Public Utilities Department
- West San Bernardino City Water District
- City of Colton Public Works Department
- Meeks & Daley Water Company (now Elsinore Valley Municipal Water Department)

- 1       ■ Riverside Highland Water Company
- 2       ■ East Valley Water District
- 3       ■ City of Rialto Water Division
- 4       ■ Muscoy Mutual Water Company No. 1

5       The well pumpage data was arranged in average quarterly values for each year. Well pumpage for each  
6       water-supply well active between January 1986 through December 1990 of the transient-state model were  
7       used in the calibration of the transient-state model and then used in the predictive simulations for the  
8       extraction scenarios. Well pumpage of each water-supply well for the last quarter of 1990 (October,  
9       November and December) are listed in Table 12 of Appendix J. The location of these wells is shown in  
10      Figure 22 of Appendix J.

11      Since the model area is represented by two layers, pumpage for each layer was estimated by well depth,  
12      location, and length of perforations. Pumpage was assigned to the upper model layer for wells perforated  
13      only in the upper aquifer. Pumpage for wells perforated only in the lower aquifer was assigned to the  
14      lower model layer. Pumpage from wells perforated in both aquifers was prorated, depending on the length  
15      of perforations in each aquifer system. The prorated discharge from these wells was allocated to the  
16      nearest nodes. As many as seven wells were grouped together to represent the composite pumpage for one  
17      model cell.

### 18      3.9 Vertical Leakance Values

19      In order to represent the hydrologic connection between the two layers of the model, vertical leakance  
20      values were estimated for the middle confining clay unit that separates the upper and lower aquifer in  
21      souther region of the model area. Leakance is the ratio of the vertical hydraulic conductivity of th  
22      material to the thickness of the middle confining clay unit. In other words, leakance is used to  
23      the rate at which water moves vertically through a particular clay unit into the aquifer. With  
24      area, some exchange of groundwater between the upper and lower aquifers occurs thro  
25      confining clay unit.

Initially when leakance values were assigned for the steady-state model, a vertical hydraulic conductivity of  $10^{-8}$  cm/sec ( $2.83 \times 10^{-5}$  ft/day) was assumed for the middle confining clay unit (Freeze and Cherry 1979). The thicknesses of the middle confining clay unit ranged from 30 to nearly 300 feet south of Shandin Hills. The resultant leakance values for the middle confining clay unit of the steady-state model ranged from  $9.43 \times 10^{-7}$  to  $1.00 \times 10^{-7}$  (ft/day)/ft (Table 1 of Appendix J).

During the calibration of the transient-state model, leakance values for the confining clay unit in the southern region of the study area were increased by factors of 10 to  $10^4$ . The leakance values for the northern edge of the confining clay unit was increased by approximately a factor of  $10^4$ ; the leakance values for the middle area of the confining clay unit next to the San Jacinto fault were reduced by a factor of 10. Figure 12 in Appendix J shows the area of the model area that contains the confining clay unit. Table 11 in Appendix J gives the representative leakance values for selective water-supply well areas that were used in the transient-state model. Table 11 in Appendix J also shows the leakance value of  $0.1 \text{ day}^{-1}$  that was used for the northern region of the model area where no substantial confining clay unit exists. This is shown for areas around the Newmark wells, Waterman Avenue well, 30th and Mountain View well, 31st and Mountain View well, and Lynwood well.

#### **4.0 EXTRACTION SCENARIO NO. 1**

##### **4.1 Objectives**

The objectives for extraction scenario no. 1 were:

- Quickly estimate the number, locations, and pumping rates of extraction wells required to capture the downgradient edge of the Newmark plume within five years; and
- Minimize extraction of uncontaminated groundwater.

## 4.2 Procedures and Data

Twelve simulations were made before the optimum simulation (Run 30C0609) was achieved for extraction scenario no. 1. The procedure described below was followed for achieving optimum Run 30C0609:

- Run 30C0609 was made using MODFLOW that ran for a time span of five years. The transient-state flow model, simulated and calibrated for the time period between January 1986 to December 1990, was used as the basis for Run 30C0609. The input data (including the well pumpage) and boundary conditions used in the calibration of the transient-state flow model were applied to Run 30C0609 for the five years of the simulation. These values are described in more detail in Section 3.0.
- Five extraction areas were added to the well input file. These five areas were located just inside the outer perimeter of the downgradient edge of the Newmark plume. Therefore, all 5 extraction areas were screened throughout layer 2 (the lower aquifer) since it is believed through geologic and hydrologic interpretation that most of the contamination exists in the lower aquifer. Therefore, all five extraction areas were screened throughout layer 2 (the lower aquifer) since it is believed that most of the contamination exists in the lower aquifer. For layer 2 of the project flow model, the screen interval equaled the top elevation minus the bottom elevation (bedrock) for layer 1. Table 1 gives the locations of the extraction areas, their pumping rates and screen intervals used in the simulation.
- PATH3D was applied to MODFLOW input data, output file and the unformatted head file for Run 30C0609. A grid file of the heads was created through the application of PATH3D. Also, pathlines were created for 24 imaginary particles placed along the outer perimeter of the lower two-thirds of the Newmark plume. Table 2 gives the locations of the imaginary particles.
- SURFER was used to produce plots of the head contours and pathlines created during the application of PATH3D.

Appendix M

Table 1

EXTRACTION AREA LOCATIONS & PUMPING RATES  
FOR EXTRACTION SCENARIO NO. 1

Extraction Area	Model Cell (x,y,z)	Screen Interval (ft)	Approximate Location	Pumping Rate (gpm)
Downgradient Edge of Newmark Plume				
7	(30,34,2)	480 to 640	200' W/of D St.; 300' N/of Highland Ave.	2000
8	(31,35,2)	350 to 610	50' W/of Arrowhead Ave.; 150' N/of 21st St.	4000
9	(32,35,2)	235 to 660	200' E/of Mt. View Ave.; 220' N/of 21st St.	4000
10	(33,35,2)	255 to 700	250' E/of Sierra Way; 100' N/of 21st St.	4000
11	(34,34,2)	380 to 780	250' E/of Sepulveda Ave.; 250' N/of Highland Ave.	2000

Note: Extraction area nos. 1 & 7 were eliminated after Run 30A0609.

## Appendix M

Table 2

### IMAGINARY PARTICLE LOCATIONS FOR EXTRACTION SCENARIO NO. 1

Particle(s)	Model Cell (x,y,z)	Particle(s)	Model Cell (x,y,z)
1	(29,32,2)	15	(30,37,2)
2 & 3	(30,33,2)	16	(31,38,2)
4 & 5	(31,33,2)	17	(32,38,2)
6 & 7	(32,33,2)	18	(33,38,2)
8 & 9	(33,33,2)	19	(34,37,2)
10 & 11	(34,33,2)	20	(35,35,2)
12	(35,32,2)	21	(35,34,2)
13	(29,34,2)	22-24	(32,37,2)
14	(29,35,2)		

#### 4.3 Results and Summary

The head contour plots for layers 1 and 2 (30CCNTR1.PLT and 30CCNTR2.PLT) and the PATH3D output file for Run 30C0609 were analyzed. Figures 2 and 3 display the head contour plots for layers 1 and 2 respectively. These figures also display the extraction areas and the imaginary particles with their pathlines. Table 3 lists the MODFLOW, PATH3D and SURFER files associated with Run 30C0609. The results and summary of the analysis are listed below:

- Initially in Run 27A0529, ten extraction areas were placed in an arc shape along the outer perimeter of the downgradient edge of the Newmark plume and each area was pumped at 2000 gpm per layer. This scenario produced capture zones for both layers that were too large and extended a long distance downgradient of the Newmark plume. However, two imaginary particles (no. 18 and 19) migrated past the extraction areas located at the southeast edge of Newmark plume. Though the southeastern edge of the Newmark plume (represented by the two imaginary particles no. 18 and 19) was not captured, it was concluded that an excessive amount of uncontaminated groundwater could be extracted from the area downgradient of the Newmark plume.
- In the next several simulations (Runs 27B0601 through 30B0609), the number, locations and pumping rates of the extraction areas were adapted. Eventually, the extraction areas were moved upgradient into the Newmark plume, approximately 2000 feet from the downgradient edge of the Newmark plume and five extraction areas were eliminated from the previous ten extraction areas. One extraction area was eliminated from the southwest end of the arc and four extraction areas were eliminated from the southeast end of the arc. Also, the pumping rates were adjusted and arranged to extract groundwater from only layer 2 (the lower aquifer), where most of the groundwater contamination is believed to exist.

# Appendix M

Table 3

## INPUT AND OUTPUT FILES FOR EXTRACTION SCENARIO NO. 1

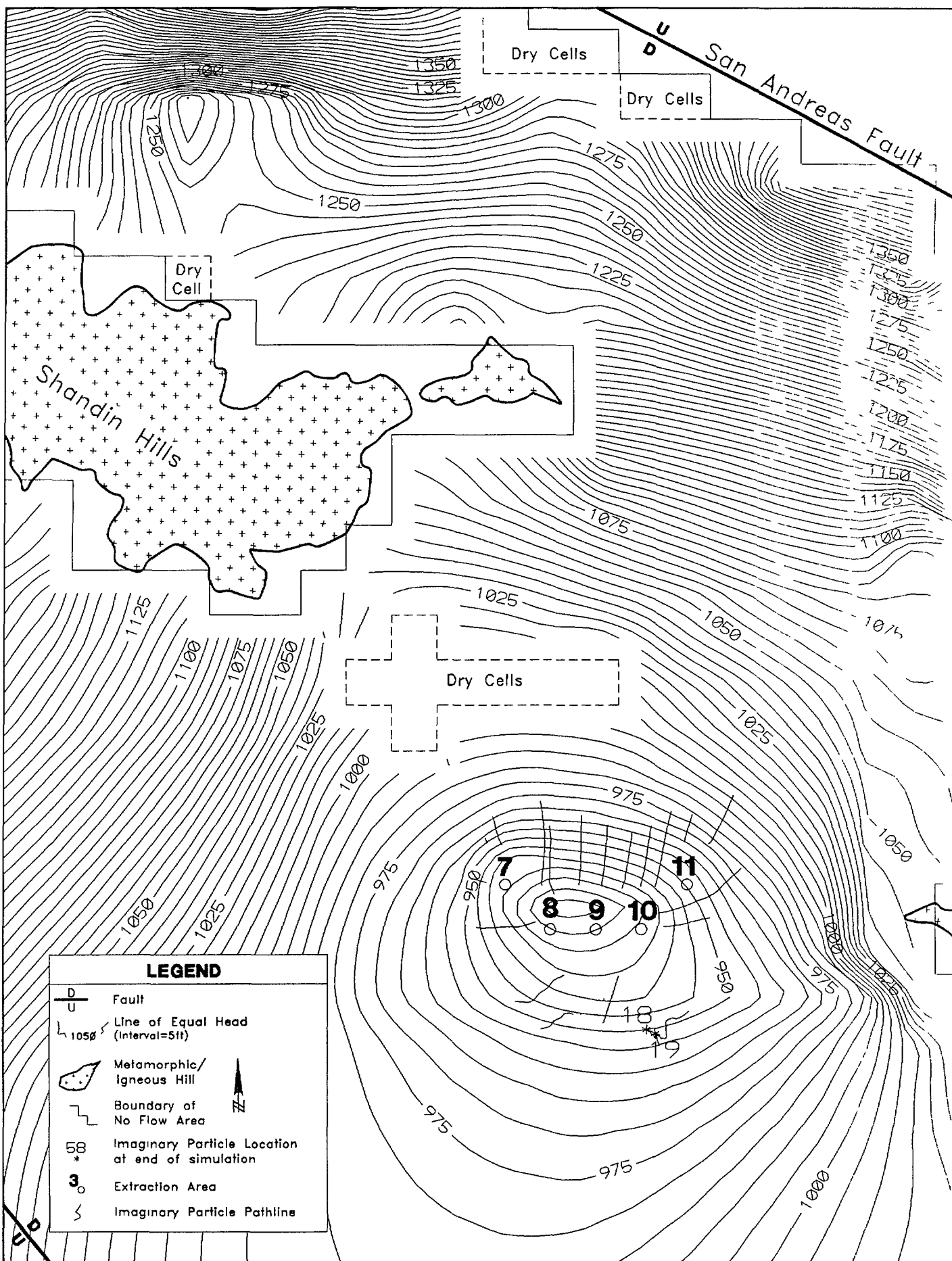
Rootname			Extension	Filename	Type of File
Run No.	Modification	Date			
30	C	06/09/92	BAS	30C0609.BAS	MODFLOW input file
30	C	06/09/92	BCF	30C0609.BCF	MODFLOW input file
30	C	06/09/92	OC	30C0609.OC	MODFLOW input file
30	C	06/09/92	PCG	30C0609.PCG	MODFLOW input file
30	C	06/09/92	RIV	30C0609.RIV	MODFLOW input file
30	C	06/09/92	WEL	30C0609.WEL	MODFLOW input file
30	C	06/09/92	GHB	30C0609.GHB	MODFLOW input file
30	C	06/09/92	EVT	30C0609.EVT	MODFLOW input file
30	C	06/09/92	BCF	30CCCELL.BCF	MODFLOW cell-by-cell flow file
30	C	06/09/92	RIV	30CCCELL.RIV	MODFLOW cell-by-cell flow file
30	C	06/09/92	WEL	30CCCELL.WEL	MODFLOW cell-by-cell flow file
30	C	06/09/92	GHB	30CCCELL.GHB	MODFLOW cell-by-cell flow file
30	C	06/09/92	EVT	30CCCELL.EVT	MODFLOW cell-by-cell flow file
30	C	06/09/92	OUT	30C0609.OUT	MODFLOW output file
30	C	06/09/92	UFM	30CHEAD.UFM	MODFLOW unformatted head file
30	C	06/09/92	INP	30CPATH.INP	PATH3D input file
30	C	06/09/92	OUT	30CPATH.OUT	PATH3D output file
30	C	06/09/92	DAT	P3DCNFG.DAT	PATH3D data file
30	C	06/09/92	DAT	P3DPLOT.DAT	PATH3D data file
30	C	06/09/92	DAT	P3DFRONT.DAT	PATH3D data file
30	C	06/09/92	DAT	P3DCAPT.DAT	PATH3D data file
30	C	06/09/92	DAT	FRONTXYZ.DAT	PATH3D data file used with SURFER
30	C	06/09/92	DAT	PATHXYZ.DAT	PATH3D data file used with SURFER
30	C	06/09/92	BLN	PATHXY.BLN	PATH3D data file used with SURFER
30	C	06/09/92	BLN	PATHXZ.BLN	PATH3D data file used with SURFER
30	C	06/09/92	BLN	PATHYZ.BLN	PATH3D data file used with SURFER

## Appendix M

Table 3 (Cont'd.)

### INPUT AND OUTPUT FILES FOR EXTRACTION SCENARIO NO. 1

Rootname			Extension	Filename	Type of File
Run No.	Modification	Date			
30	C	06/09/92	GRD	30CCNTR.GRD	SURFER grid file of head contours
30	C	06/09/92	GRD	30CCNTR2.GRD	SURFER grid file of head contours
30	C	06/09/92	PLT	30CCNTR.PLT	SURFER plot file of head contours
30	C	06/09/92	PLT	30CCNTR2.PLT	SURFER plot file of head contours
30	C	06/09/92	DAT	XTRWELLS.DAT	Data file containing locations of extraction wells



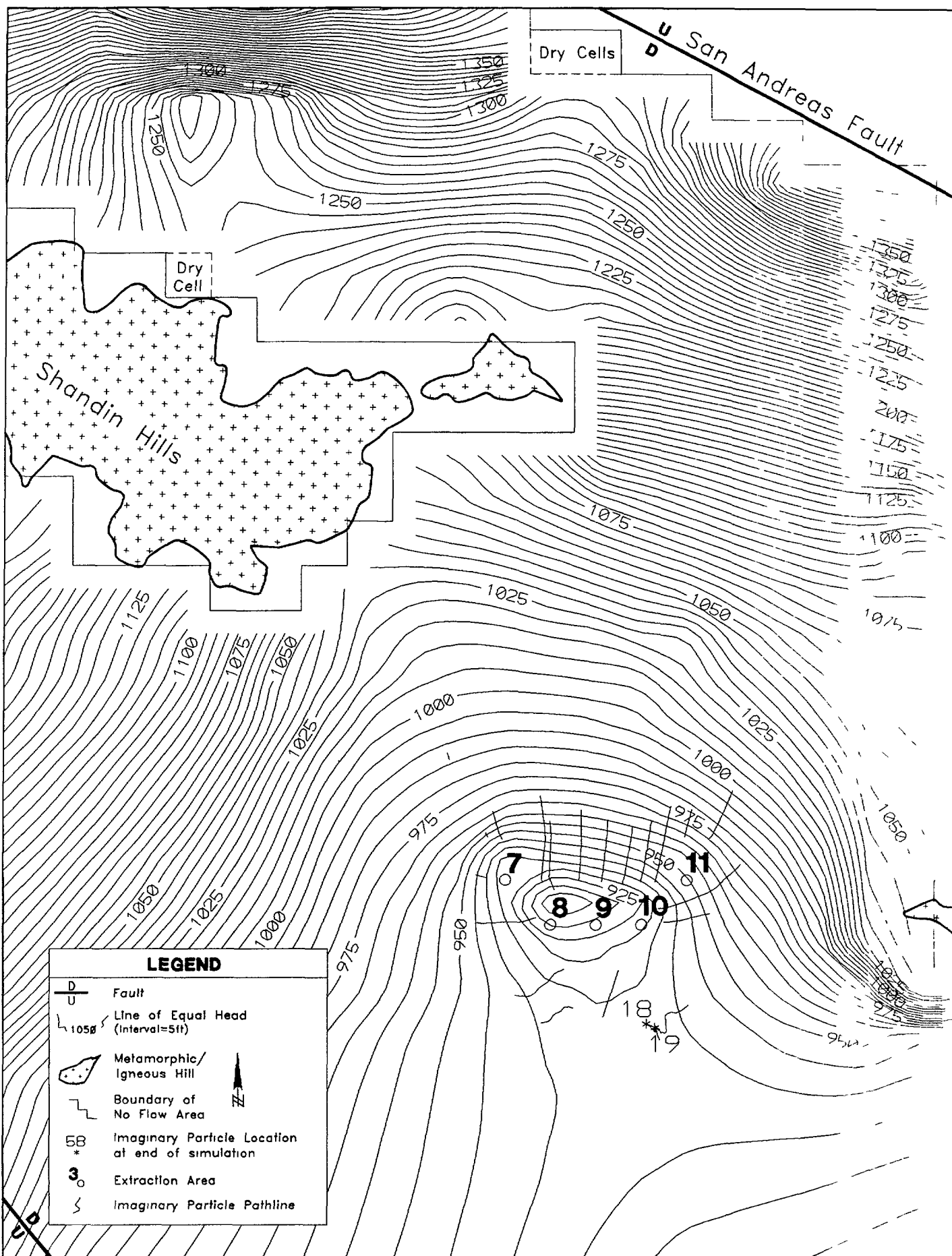
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ARCS EPA REGIONS IX & X WA NO 64-10-0146

**FIGURE 2**  
HEAD CONTOUR AND PATHLINE PLOT OF EXTRACTION  
SCENARIO NO 1, LAYER 1 (UPPER AQUIFER)

0 1000 2000  
5' ALL IN FEET



**LEGEND**

$\frac{D}{U}$  Fault

Line of Equal Head (Interval=5ft)

Metamorphic/Igneous Hill

Boundary of No Flow Area

Imaginary Particle Location at end of simulation

Extraction Area

Imaginary Particle Pathline

The final positions of the five extraction areas for extraction scenario no. 1 are shown in Figures 2 and 3. The total pumping rate for all five extraction areas was 16,000 gpm. Table 1 contains the individual pumping rates for the five extraction areas.

- All 24 imaginary particles were captured except imaginary particles no. 18 and 19 located on the southeast perimeter of the downgradient edge of the Newmark plume (just south of extraction area no. 5). However, both of these imaginary particles were migrating slowly towards extraction area no. 10. It was assumed that these two imaginary particles would be captured during the 35-year simulations as the capture zones grew.

## **5.0 EXTRACTION SCENARIO NO. 2**

### **5.1 Objectives**

The objectives for extraction scenario no. 2 were:

- Quickly estimate the number, locations, and pumping rates of extraction areas required to capture the Newmark wellfield of the Newmark plume within five years; and
- Avoid creation of dry cells in the area north of Shandin Hills during the simulation.

### **5.2 Procedure and Data**

Three simulations were made before the optimum simulation (Run 31D0611) was achieved for extraction scenario no. 2. The procedure described below was followed for achieving optimum Run 31D0611:

- Run 31D0611 was made using MODFLOW that ran for a time span of five years. The transient-state flow model, simulated and calibrated for the time period between January 1986 to December 1990, was used as the basis for Run 31D0611. The input data (including the well pumpage) and

boundary conditions used in the calibration of the transient-state flow model were applied to Run 31D0611 for the five years of simulation. The input data and boundary conditions are described in more detail in Section 3.0.

- A total of five extraction areas were used to remediate the Newmark wellfield of the Newmark plume. Four of these five extraction areas were the existing Newmark water-supply wells pumping at their normal rates from January 1986 through December 1990. One extraction area was added south of the Newmark wells and was pumping at 1000 gpm for the five years. The existing Newmark wells were screened in several different intervals throughout the upper aquifer. However, due to a limitation in the MODFLOW program, extraction of groundwater from the project flow model was not restricted to separate zones within each model layer. Therefore, the existing Newmark wells and the additional extraction area no. 5 were screened throughout layer 1 (the upper aquifer). Also, for layer 1 of the project flow model, the screen interval equaled the head value minus the bottom elevation for layer 1. The screen interval for layer 1 changed when the head in layer 1 changed during the simulation. Table 4 gives the locations of the extraction areas, their pumping rates and screen intervals used in the simulation.

- PATH3D was applied to MODFLOW input data, output file and the unformatted head file for Run 31D0611. A grid file of the heads was created through the application of PATH3D. Also, pathlines were created for ten imaginary particles placed upgradient of the Newmark wellfield in a north/south lineament. Table 5 gives the locations of the imaginary particles.

- SURFER was used to produce plots of the head contours and pathlines created during the application of PATH3D.

# Appendix M

Table 4

## EXTRACTION AREA LOCATIONS & PUMPING RATES FOR EXTRACTION SCENARIO NO. 2

Extraction Area	Model Cell (x,y,z)	Screen Interval (ft)	Approximate Location	Pumping Rate (gpm)
Newmark wellfield of Newmark Plume				
Newmark 1 <sup>a</sup>	(23,18,1)	995 to 1248 <sup>d</sup>	NE corner of A St. & Western Ave.	0 to 2910 <sup>b</sup>
Newmark 2 <sup>a</sup>			175' S/of Reservoir Dr.; 40' W/of Magnolia Dr.	
Newmark 3 <sup>a</sup>			95' N/of 42nd St.; 280' E/of Western Ave.	
Newmark 4 <sup>a</sup>	(23,17,1)	1025 to 1270 <sup>d</sup>	65' S/of Reservoir Dr.; 50' E/of Western Ave.	0 to 1585 <sup>c</sup>
5	(23,19,1)	995 to 1265 <sup>d</sup>	500' S/of 42nd St.; 450' W/of 4th Ave.	1000

<sup>a</sup> Existing water-supply well.

<sup>b</sup> Total pumping rate range for Newmark 1,2 & 3 for 1986 through 1990 was used in the 5-year simulation.

<sup>c</sup> Pumping rate range for Newmark 4 for 1986 through 1990 was used in the 5-year simulation.

<sup>d</sup> Initial head in layer 1 (upper aquifer). The screen interval in layer 1 equals the head value in layer 1 minus the bottom elevation for layer 1.

## Appendix M

Table 5

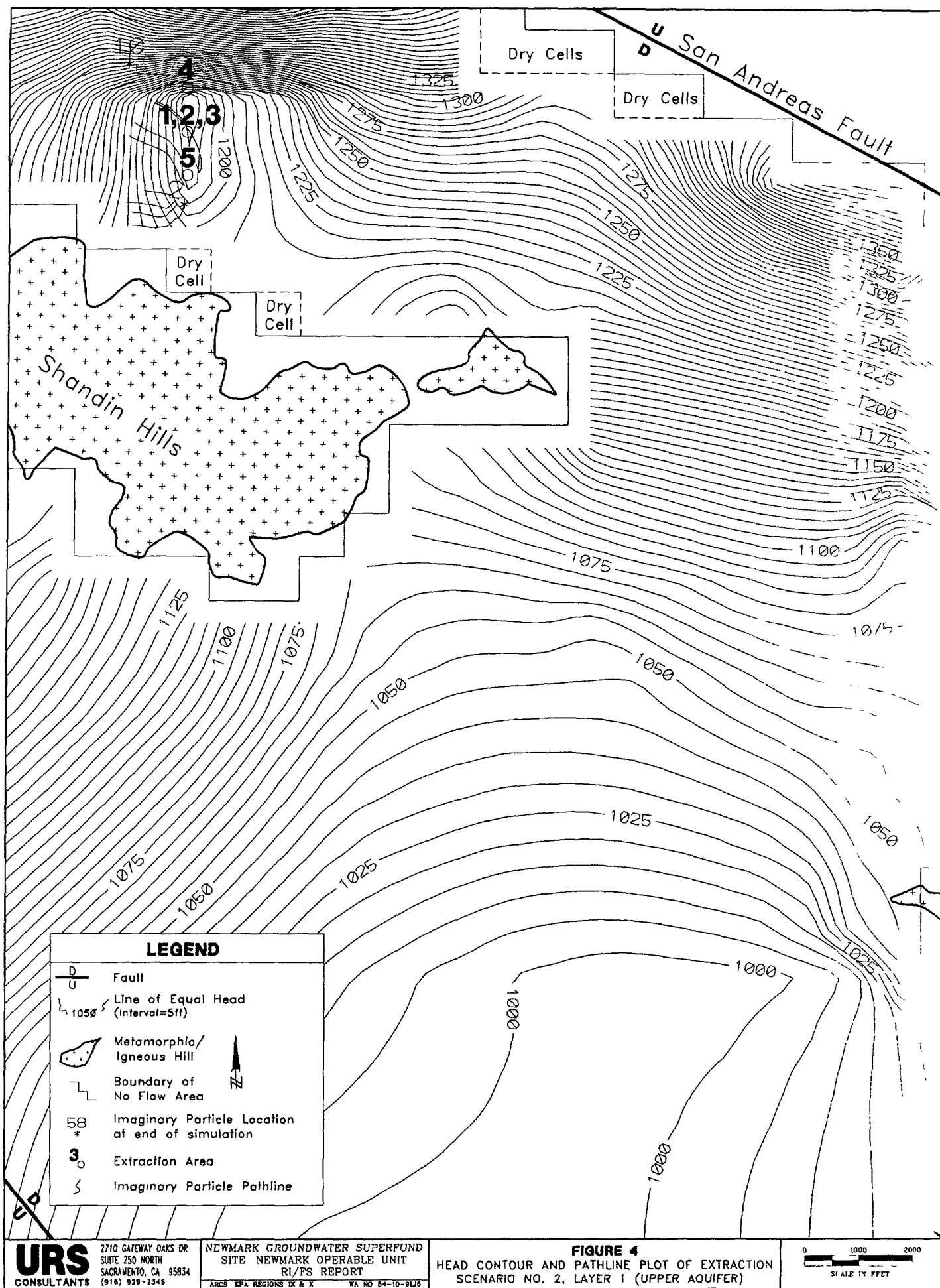
### IMAGINARY PARTICLE LOCATIONS FOR EXTRACTION SCENARIO NO. 2

Particle	Model Cell (x,y,z)	Particle	Model Cell (x,y,z)
1	(22,20,1)	6	(22,18,2)
2	(22,20,2)	7	(22,17,1)
3	(22,19,1)	8	(22,17,1)
4	(22,19,1)	9	(22,16,1)
5	(22,18,1)	10	(22,16,1)

## Results and Summary

The head contour plots for layers 1 and 2 (31DCNTR1.PLT and 31DCNTR2.PLT) and the PATH3D output file for Run 31D0611 were analyzed. Figures 4 and 5 display the head contour plots for layers 1 and 2, respectively. These figures also display the extraction areas and the imaginary particles with their pathlines. Table 6 lists the MODFLOW, PATH3D and SURFER files associated with Run 31D0611. The results and summary of the analysis are listed below:

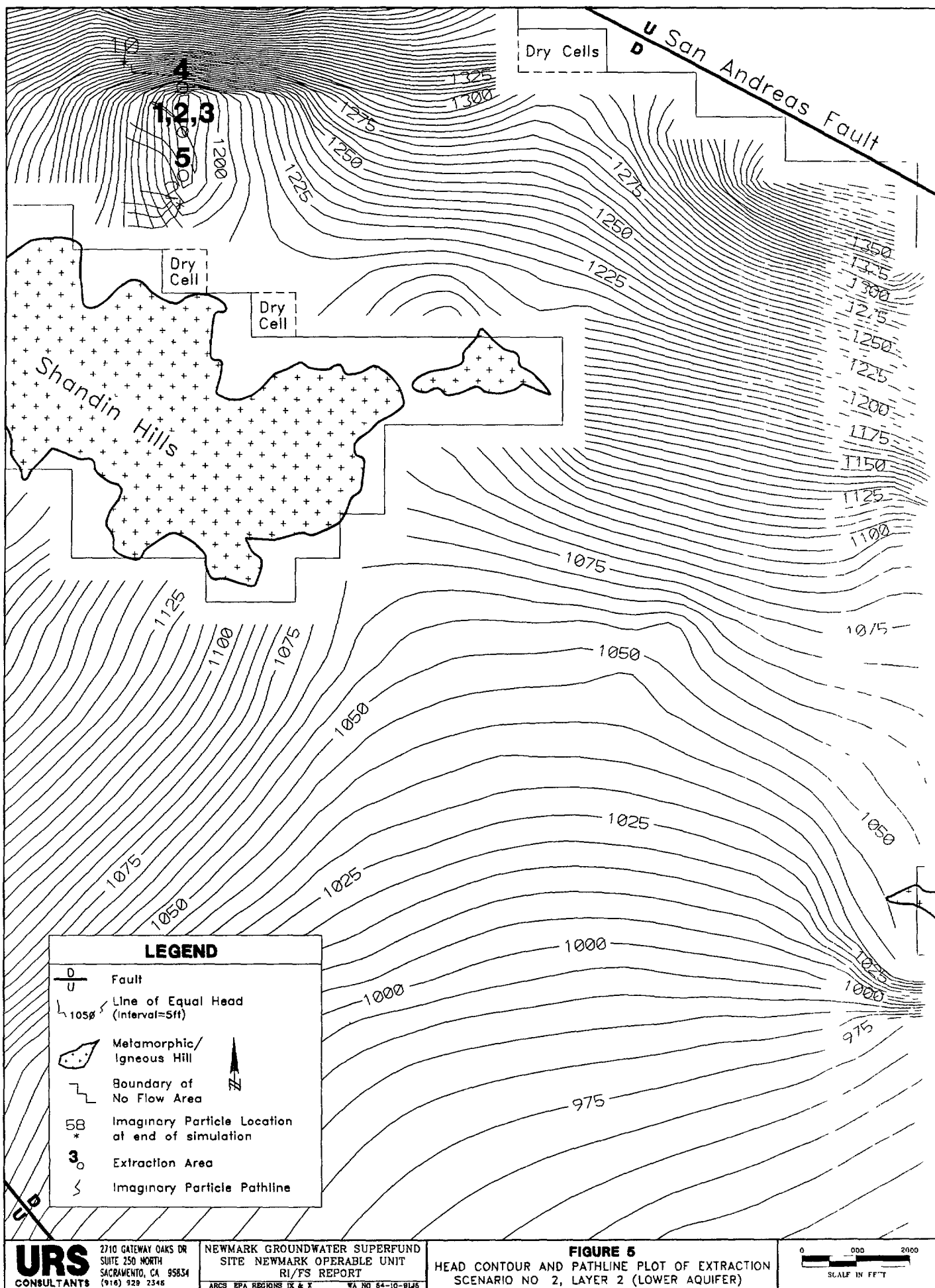
- Initially in Run 31A0610, two extraction areas were placed 820 and 2640 feet south of the Newmark wells. Each extraction area was pumped at 2000 gpm in layer 1. This scenario produced a capture zone in layer 1 (the upper aquifer) that was too large. The capture zone for layer 2 looked like the same capture zone produced in layer 1 since these two layers were interconnected as one aquifer in the project flow model for this section of the model area;
- In Run 31B0610, just the Newmark wells were pumped at their normal rates for January 1986 through December 1990. An inadequate capture zone was produced that allowed four imaginary particles south of the Newmark wells to migrate downgradient;
- In Run 31C0611, the Newmark wells were pumped at their maximum capacities for five years. This scenario caused the cells in this section of the model area to go dry; and
- In Run 31D0611, the specifications for the extraction areas in extraction scenario no. 2 were reached. One extraction area was placed 820 feet south of the Newmark wells and was pumped at 1000 gpm. The Newmark wells were pumped at their normal rates for January through December 1990.



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ARCS EPA REGIONS IX & X WA NO 64-10-01J6

# Appendix M

Table 6

## INPUT AND OUTPUT FILES FOR EXTRACTION SCENARIO NO. 2

Rootname			Extension	Filename	Type of File
Run No.	Modification	Date			
31	D	06/11/92	BAS	31D0611.BAS	MODFLOW input file
31	D	06/11/92	BCF	31D0611.BCF	MODFLOW input file
31	D	06/11/92	OC	31D0611.OC	MODFLOW input file
31	D	06/11/92	PCG	31D0611.PCG	MODFLOW input file
31	D	06/11/92	RIV	31D0611.RIV	MODFLOW input file
31	D	06/11/92	WEL	31D0611.WEL	MODFLOW input file
31	D	06/11/92	GHB	31D0611.GHB	MODFLOW input file
31	D	06/11/92	EVT	31D0611.EVT	MODFLOW input file
31	D	06/11/92	BCF	31DCELL.BCF	MODFLOW cell-by-cell flow file
31	D	06/11/92	RIV	31DCELL.RIV	MODFLOW cell-by-cell flow file
31	D	06/11/92	WEL	31DCELL.WEL	MODFLOW cell-by-cell flow file
31	D	06/11/92	GHB	31DCELL.GHB	MODFLOW cell-by-cell flow file
31	D	06/11/92	EVT	31DCELL.EVT	MODFLOW cell-by-cell flow file
31	D	06/11/92	OUT	31D0611.OUT	MODFLOW output file
31	D	06/11/92	UFM	31DHEAD.UFM	MODFLOW unformatted head file
31	D	06/11/92	INP	31DPATH.INP	PATH3D input file
31	D	06/11/92	OUT	31DPATH.OUT	PATH3D output file

**Appendix M**

**Table 6 (Cont'd.)**

**INPUT AND OUTPUT FILES FOR EXTRACTION SCENARIO NO. 2**

<b>Rootname</b>			<b>Extension</b>	<b>Filename</b>	<b>Type of File</b>
<b>Run No.</b>	<b>Modification</b>	<b>Date</b>			
31	D	06/11/92	DAT	P3DCNFG.DAT	PATH3D data file
31	D	06/11/92	DAT	P3DPLOT.DAT	PATH3D data file
31	D	06/11/92	DAT	P3DFRONT.DAT	PATH3D data file
31	D	06/11/92	DAT	P3DCAPT.DAT	PATH3D data file
31	D	06/11/92	DAT	FRONTXYZ.DAT	PATH3D data file used with SURFER
31	D	06/11/92	DAT	PATHXYZ.DAT	PATH3D data file used with SURFER
31	D	06/11/92	BLN	PATHXY.BLN	PATH3D data file used with SURFER
31	D	06/11/92	BLN	PATHXZ.BLN	PATH3D data file used with SURFER
31	D	06/11/92	BLN	PATHYZ.BLN	PATH3D data file used with SURFER
31	D	06/11/92	GRD	31DCNTR.GRD	SURFER grid file of head contours
31	D	06/11/92	GRD	31DCNTR1.GRD	SURFER grid file of head contours
31	D	06/11/92	PLT	31DCNTR.PLT	SURFER plot file of head contours
31	D	06/11/92	PLT	31DCNTR1.PLT	SURFER plot file of head contours
31	D	06/11/92	DAT	XTRWELLS.DAT	Data file containing locations of extraction wells

All imaginary particles were captured except two imaginary particles located northwest of the Newmark wells. However, both of these imaginary particles were migrating slowly towards Newmark well no. 4. It was assumed that these two imaginary particles would be captured during the 35-year simulations as the capture zone grew.

## **6.0 EXTRACTION SCENARIO NO. 3**

### **6.1 Objectives**

The objectives for extraction scenario no. 3 were:

- Quickly estimate the number, locations, and pumping rates of extraction areas required to capture the middle area of the Newmark plume within 5 years; and
- Avoid creation of dry cells in the area north and east of Shandin Hills during the simulation.

### **6.2 Procedure and Data**

Two simulations were made before the optimum simulation (Run 32B0612) was achieved for extraction scenario no. 3. The procedure described below was followed for achieving optimum Run 32B0612:

- Run 32B0612 was made using MODFLOW that ran for a time span of five years. The transient-state flow model, simulated and calibrated for the time period between January 1986 to December 1990 was used as the basis for Run 32B0612. The input data (including the well pumpage) and boundary conditions used in the calibration of the transient-state flow model were applied to Run 32B0612 for the five years of simulation. The input data and boundary conditions are described in more detail in Section 3.0.

- 1       ■ Two extraction areas were used to remediate the middle area of the Newmark plume. These two  
2       extraction areas were located adjacent to the northeast edge of Shandin Hills and arranged in a  
3       northeast lineament. Due to a limitation in the MODFLOW program, extraction of groundwater  
4       from the project flow model was not restricted to separate zones within each model layer.  
5       Therefore, the extraction areas were both screened throughout layer 1 (the upper aquifer). For  
6       layer 1 of the project flow model, the screen interval equaled the head value minus the bottom  
7       elevation for layer 1. The screen interval for layer 1 changed when the head in layer 1 changed  
8       during the simulation. Table 7 gives the locations of the extraction areas, their pumping rates and  
9       screen intervals used in the simulation.
  
- 10      ■ PATH3D was applied to MODFLOW input data, output file and the unformatted head file for  
11      Run 32B0612. A grid file of the heads was created through the application of PATH3D. Also,  
12      pathlines were created for six imaginary particles placed upgradient and adjacent to the two  
13      extraction areas. Table 8 details the locations of the imaginary particles.
  
- 14      ■ SURFER was used to produce plots of the head contours and pathlines created during the  
15      application of PATH3D.

## 16      Results and Summary

17      The head contour plots for layers 1 and 2 (32BCNTR1.PLT and 32BCNTR2.PLT) and the PATH3D output  
18      file for Run 32B0612 were analyzed. Figures 6 and 7 display the head contour plots for layers 1 and 2,  
19      respectively. These figures also display the extraction areas and the imaginary particles with their  
20      pathlines. Table 9 lists the MODFLOW, PATH3D and SURFER files associated with Run 32B0612. The  
21      results and summary of the analysis are listed below: